The American Water System

Annual Review of Research

1999

Research Expertise

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Exhibit 5.5

SUMMARY

The 1999 review focuses on the research associates who devote their expertise to make the mission of the American Water System Research Program successful. The accomplishments of these men and women include completion of five research reports:

- Treatment Strategies for Spent Filter Backwash Water
- Occurrence of Viruses in Ground Water in the United States
- The Effect of Wastewater Discharge and Rainfall on *Giardia* and *Cryptosporidium* in East Central Illinois
- Enhanced Solids Contact Clarification for Removal of Natural Organic Matter
- Radon Treatment Cost Evaluation

In addition, the Research Group delivered 52 presentations at local, regional, national or international conferences, seminars or workshops; publication of 33 manuscripts in peer-reviewed journals, books or conference proceedings; visits and discussions with 17 researchers; involvement in 34 national committees; training and technical support for American utility subsidiaries and a number of water utilities nationwide, and involvement in the development of a number of drinking water regulations. One highlight of the year was the award from the AWWA Distribution and Plant Operations Division for the "best paper" published in the Journal of the American Water Works Association.

INTRODUCTION

This 1999 review provides an opportunity to recap the year's activities and to highlight the associates who accomplish the overall mission of the American Water System Research Program, namely, "to conduct research and investigations on water quality concerns and other issues to support Company operations." As such, this report will not dwell on the details of any one activity, these details are outlined in monthly progress reports, but the purpose will be to demonstrate how all these activities contributed to the achievement of the research goals.

CONTENTS

PERSONNEL

The Research Program is directed to meet the specific needs of the American Water System (AWS). These investigations may be specific to a single company (e.g., pilot studies to support engineering design, or examine a specific water quality concern), or more general solution-oriented research (to determine the compliance or impact of a pending regulation, or to evaluate new technologies). The research results are used to support immediate operational changes and plan for long-term modifications. Summarized below is a description of the 1999 active or completed research projects (a complete list of all projects is found at the end of this report on page 25).

Currently, the research staff consists of 19 professionals: director, senior environmental engineer, senior environmental scientist, four environmental scientists, post doctoral associate, senior analyst, eight analysts, technician, and a secretary. Research personnel are distributed between two locations; four individuals at the corporate office in Voorhees, NJ, and fifteen at the Quality Control and Research Laboratory in Belleville, IL. The total budget for the research program in 1999 was approximately $3.0 million.

Staff changes included the addition of Dr. Kwok-Keung Au, post doctoral associate; Robin Casale, environmental scientist; Stacey Dulaney, analyst; Dr. Mohammad Karim, senior analyst; Jeff Nieroda, analyst; Chris Rapoff, analyst.

Voorhees Staff.
Richard Gullick, Harish Arora, Richard Moser, Robin Casale, Mark LeChevallier

Belleville Staff:
Back row: Dale Young, Ramon Aboytes, George Di Giovanni, Mike Spinner, Nancy Shaw, Stacy Dulaney, Chris Rapoff, Tracey Clover, Jeff Nieroda.

Front row: Debbie Verges, Bob Kozik, Mohammad Karim, Cheryl Norton, Felicia Abrams.

Research Projects

Research Agenda

The American System research describes the development of a work plan and outlines the allocation of research resources until the year 2004. The basis of the agenda was a questionnaire sent to managers, engineers, and water quality personnel at the corporate, regional, and utility subsidiaries. The results of the questionnaire were tabulated and sent to a Research Advisory Group for evaluation. The Advisory Group conducted a one-day meeting to develop a detailed prioritized list of 67 research topics. This list was melded with existing projects to develop a specific 5-year agenda. It should be emphasized that the agenda is primarily for planning purposes and can be made responsive to changes in scope and content as required by future events.

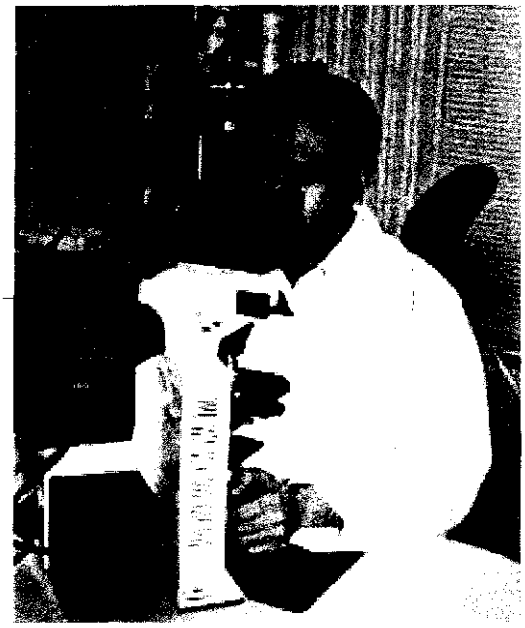
Regulatory-Driven Research

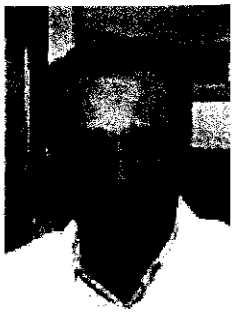
Regulatory-driven research provides information relevant to the applicability, impact, or compliance with pending USEPA mandates. The research results allow American to comment in an authoritative manner on the utility or need for a proposed regulation. In several cases, this information has been an important factor in modifying a regulatory proposal. Listed below are several pending regulations that will impact utility subsidiary operations and a summary of the related AWS research effort:

Disinfectant/Disinfection By-Product Rule

The Disinfectant/Disinfection By-Product Rule (D/DBP) is anticipated to reduce the Maximum Contaminant Level (MCL) for trihalomethanes (THMs). In addition, new requirements for haloacetic acids (HAAs) and TOC removal will have a major impact on utility subsidiary operations. AWS research includes:

- *Enhanced Solids Contact Clarification for NOM Removal*
  The project focused on the removal of natural organic matter (NOM) and particulate material using enhanced coagulation techniques in sludge blanket or solid contact clarifiers. The study used full-scale facilities with analytical tests performed before and after treatment process interventions. Experiments include: improved particulate reduction, enhanced coagulation, biologically active sludge blankets, and powdered activated carbon additions. Completed in 1999.





- *Nanofiltration for Control of DBP Precursors and Pathogenic Microorganisms*
  Nanofiltration has the potential to remove disinfection by-product (DBP) precursors, organic carbon, hardness, turbidity, microbes, and other particulates in water. This project examines the integration of nanofiltration into conventional treatment. The work is partially funded by AWWARF and is performed in collaboration with University of Central Florida, and KIWA – the Dutch research agency. Anticipated completion in 2000.

- *Formation, Occurrence, Stability, and Dominance of HAAs and THMs in Treated Drinking Water*
  This project, performed in collaboration with the North Carolina University and partially funded by AWWARF, evaluates the fate of THMs and HAAs during treatment and distribution. Two parallel trains, one with conventional filtration and other with a granular activated carbon filter-adsorber, were monitored at the East St. Louis water treatment plant. Anticipated completion in 2000.

Enhanced Surface Water Treatment Rule

The Enhanced Surface Water Treatment Rule will provide additional treatment requirements for *Giardia* and *Cryptosporidium*. This regulation could have a substantial cost impact on treatment plant operations.

- *Monitoring of Cryptosporidium in Finished Drinking Water*
  Using the cell culture/polymerase chain reaction (CC-PCR) method for detection of viable oocysts, this study will collect 24 monthly samples from the combined filter effluent of approximately 80 surface water treatment plants. The project will provide conclusive data on the effectiveness of conventional treatment for control of *Cryptosporidium*. Anticipated completion in 2002.

- *Study of Water Quality Improvements During Bank Filtration of Filtered Waters*
  This project, performed in collaboration with the Johns Hopkins University and partially funded by the U.S. Environmental Protection Agency, examines the benefit of placing shallow wells along side a river and using the river bank to filter turbidity, microbes, and reduce organic carbon levels in the treated water. The study is being conducted at three sites in Indiana and Missouri. Anticipated completion in 2001.

Groundwater Rule

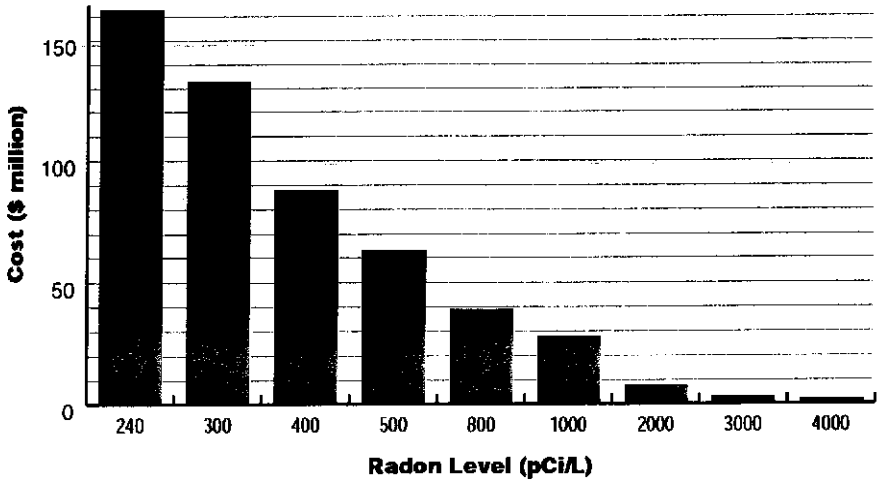
The Groundwater Rule will require an assessment of groundwater supplies primarily as a means of preventing waterborne virus outbreaks. With nearly 600 wells in the American System, this regulation could require capital improvements to provide disinfection contact basins at each well site.

- *Occurrence of Viruses in Ground Waters in the United States*
  This study, which is partially funded by AWWARF and the USEPA, examined more than 550 wells to determine the presence of waterborne viruses. The study collected water from representative wells from various hydrogeologic conditions to determine factors that can be associated with the occurrence of viruses in groundwater. Completed October 1999.

Radon Rule

The proposed Radon Rule is expected to establish a Maximum Contaminant Level (MCL) of 300 pCi/L for radon, with a higher alternative MCL (AMCL) of 4,000 pCi/L available for states that adopt a multi-media mitigation program to reduce the risk of radon from air exposure routes. The MCL would have a significant impact on many utility subsidiary operations.

- *Radon Treatment Cost Evaluation*
  An investigation estimated the capital cost impact associated with the proposed Radon Rule. Groundwater supplies that could potentially require treatment were identified, and capital cost estimates were made for installing aeration facilities for radon removal. Completed December 1999.



Regulation of Washwater Recycle

The 1996 Safe Drinking Water Act amendments direct the US Environmental Protection Agency to develop a regulation within three years for the recycle of filter backwash water. Because washwater recycling is a common practice within American (and the water industry), this regulation could have serious impacts on filter plant operation and disposal options.

- *Treatment Strategies for Spent Filter Backwash Water*
  This study, conducted in collaboration with Environmental Engineering of Technology and partially funded by AWWARF, examines the occurrence of oocysts in raw and backwash water, evaluates appropriate treatment technologies, and evaluates the cost impact to achieve various levels of *Cryptosporidium* removal. Completed October 1999.

Solution-Oriented Research

Solution-oriented research is aimed at solving a particular need, or set of needs within the American System. These studies seek to provide information to improve water quality, resolve a specific concern, or optimize drinking water operations.

Water Quality Operations

- *Changes in Biostability Following Implementation of Biological Treatment*
  This AWWARF-sponsored project is a collaborative effort between Montgomery-Watson, American Water Works Service Company, University of Central Florida, and Lyonnaise des Eaux. The study analyzes the long-term biostability response of full-scale distribution systems following the introduction of ozonation or membrane treatment. Anticipated completion in 2000.

- *Occurrence and Problems Associated with Contaminants in Drinking Water Treatment Chemicals*
  This AWWARF-sponsored project is performed in collaboration with Environmental Engineering & Technology, Inc. This project investigates control measures to prevent water quality and plant reliability problems associated with impurities in water treatment chemicals. Anticipated completion in 2000.

- *Pathogen Intrusion into the Distribution System*
  This AWWARF-sponsored project is a collaborative effort between Economic and Engineering Services, Inc., American Water Works Service Company, the University of Kentucky, and the City of Laval, Quebec to examine mechanisms by which finished drinking water could become contaminated in the distribution system. The project seeks to develop a prioritized action plan for protecting treated drinking water. Anticipated completion in 2000.

- *Continuous Monitoring of Source Waters and Spill Control Response*
  Rapid response to spills and other changes in source water quality is necessary to protect customers from potentially harmful contaminants, determine appropriate changes in treatment strategy, and ensure compliance with environmental regulations. Conducted in cooperation with AWWARF, this research will identify the current state of the science for early warning and source water monitoring systems, and provide recommendations of monitoring protocol for vulnerable watersheds. Anticipated completion in 2001.

- *Manganese Control and Permanganate Residual Measurement*
  This project will identify issues related to measurement of manganese in water. Recommendations for improved control strategies will be developed as well as an evaluation of commercially available permanganate residual measurement analyzers. Anticipated completion in 2001.

- *Practical Taste-and-Odor Methods for Routine Operations: Decision Tree*
  Andrea Dietrich of Virginia Polytechnic Institute heads this AWWARF-sponsored project. The goal of this project is to develop practical and simple sensory analysis methods that can be used to monitor taste-and-odor episodes in drinking water. American subsidiaries will evaluate this new approach. Anticipated completion in 2001.

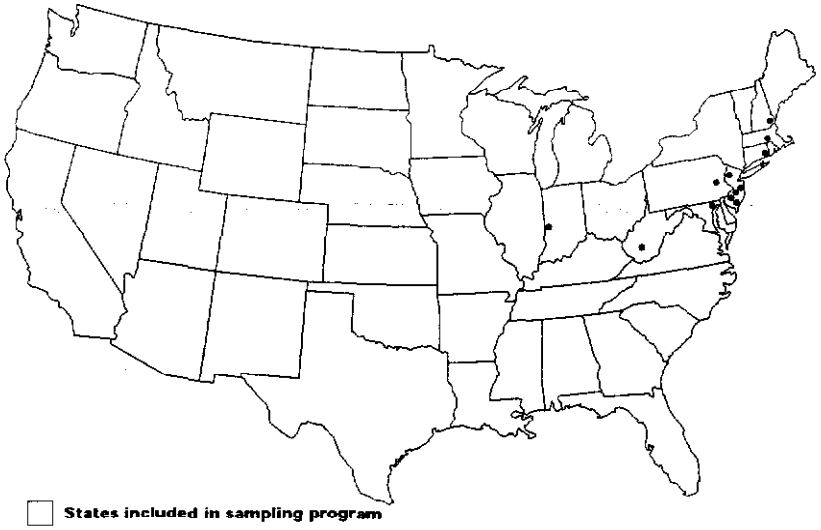
Information to Resolve a Specific Concern

- *Occurrence and Control of* Mycobacterium avium *Complex*

  Mycobacterium avium complex includes a group of opportunistic pathogens that can grow in drinking water biofilms. This AWWARF-funded project, in collaboration with Mycobacterium experts from Virginia Institute of Technology, is examining selected systems to determine the occurrence of the organisms in drinking water and approaches to limit its concern. Anticipated completion in 2000.

- *Occurrence of Perchlorate and Methyl Tertiary Butyl Ether (MTBE) in Source Waters of the American Water System*

  This study compiled Perchlorate and Methyl Tertiary Butyl Ether (MTBE) monitoring data from wells within the American System to determine the extent and magnitude of occurrence of these compounds. Manuscripts were prepared for each compound and submitted to *Journal American Water Works Association* for publication. Completed July 1999.



- *Pharmaceutically Active Compounds*

  The presence of pharmaceutically active compounds in drinking water source waters is a growing concern. These compounds represent a wide variety of antibiotics, analgesics, cholesterol-lowering drugs, chemotherapy drugs, hormones, narcotics, and psychomotor stimulants. This project will investigate analytical methodologies and identify source water occurrence for these compounds. Anticipated completion in 2001.

New Technologies

One of the functions of the Research Program is to examine new technologies that might have application within the AWS. The advantages, limitations, and cost benefits are independently evaluated in an objective and unbiased manner. The research also determines where the new technologies might be used within the AWS.

- *Cryptosporidium parvum Viability Assay Using Integrated Cell Culture and PCR*

  This project integrates the advantages of cell culture and polymerase chain reaction (PCR) methods with a systematic validation of the developed methods and environmental testing. The approach provides a rapid, highly sensitive, laborsaving assay for measurement of viable and infective *Cryptosporidium parvum* oocysts in water samples. A patent application has been filed for the test. Anticipated completion in 2000.

- *Characterizing NOM using TMAH Thermochemolysis*

  This project, conducted under the direction of Dr. Fred Cannon of Pennsylvania State University and partially funded by the National Science Foundation, will investigate a new method to characterize natural organic matter (NOM) using a tetra methyl ammonium hydroxide (TMAH) gas chromatography, mass spectroscopy (GC-MS) technique. By obtaining a more comprehensive understanding of NOM removal through treatment processes, organic carbon removal can be maximized while minimizing disinfection by-product formation. Anticipated completion in 2001.

Management Issues

Research is also directed at issues that impact management decisions and/or corporate policies. Data are collected, analyzed and presented in a manner that can either support or modify company procedures, policies or direction.

- *Maintenance and Staffing*

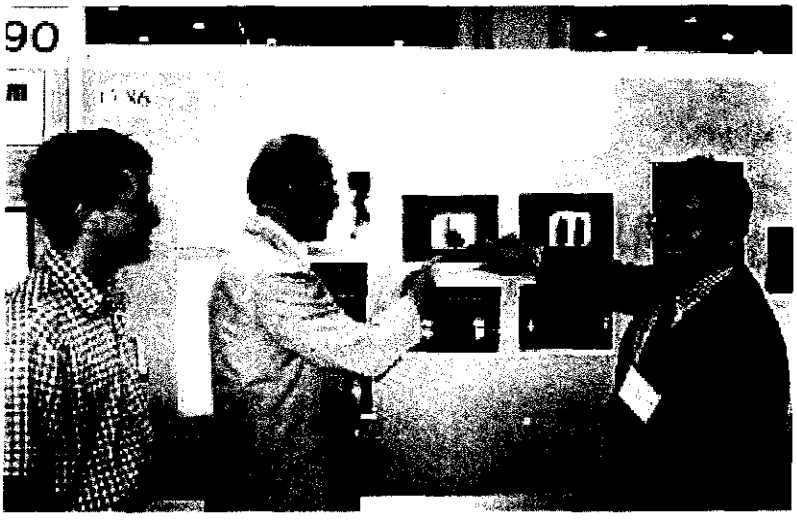
  The objective of this study is to determine appropriate levels of maintenance and associated staff to ensure proper operation and reliability of equipment with drinking water treatment plants. A database will be developed to develop site-specific maintenance programs that will detail recommended maintenance procedures, frequency, and labor-hour, and skill level requirements. Anticipated completion in 2002.

Technology Transfer and AWS Visibility

Research Program. Communicating the results and making that information usable at the operating level is critical if the Program is to be successful. Distribution of final reports, updates via monthly activity reports, and training through specific in-house programs are some of the mechanisms by which AWS personnel benefit from the Research Program. Additionally, American fulfills a commitment to the entire water industry by sharing its information through presentations, publications and direct contacts. These activities raise the visibility of the AWS and acknowledge its leadership role within the industry. This visibility is not completely altruistic, it benefits the company in its dealing with State and Federal regulators, funding agencies, and maintains a reputation for quality, excellence and dependability.

Listed below is an accounting of presentations, seminars, publications, and other activities conducted by members of the Research Program beyond their typical in-house duties:

Presentations/Seminars



Morteza Abbaszadegan

February 18 Presentation at the AWWARF Technology Transfer Conference in Fort Lauderdale, FL entitled "Occurrence of Viruses in Ground Water: A National Study."

March 8 Presentation on "Advanced Methods For The Detection Of Microorganisms In Environmental Samples" at a biotechnology conference in Abu Dhabi, the United Arab Emirates.

May 31 Poster presentation at the 99th General Meeting of the American Society of Microbiology in Chicago, IL entitled "Development of a homogeneous fluorescent PCR assay for the detection of *Cryptosporidium parvum*."

Ramon Aboytes

May 31 Poster presentation at the 99th General Meeting of the American Society of Microbiology in Chicago, IL, entitled "Distribution of *Cryptosporidium* and *Giardia* in Surface Waters".

November 1 Presentation at the Water Quality Technology Conference 1999 in Tampa, FL entitled "Finished Water Monitoring for Infectious *Cryptosporidium* Oocysts using Immunomagnetic Separation (IMS) and Cell Culture-Polymerase Chain Reaction Method (CC-PCR)".

Harish Arora

March 28 Presentation at the Particle Measurement and Characterization in Drinking Water Treatment Symposium, Nashville, TN; entitled "Application of Particle Counting to Enhance Water Treatment Operations"

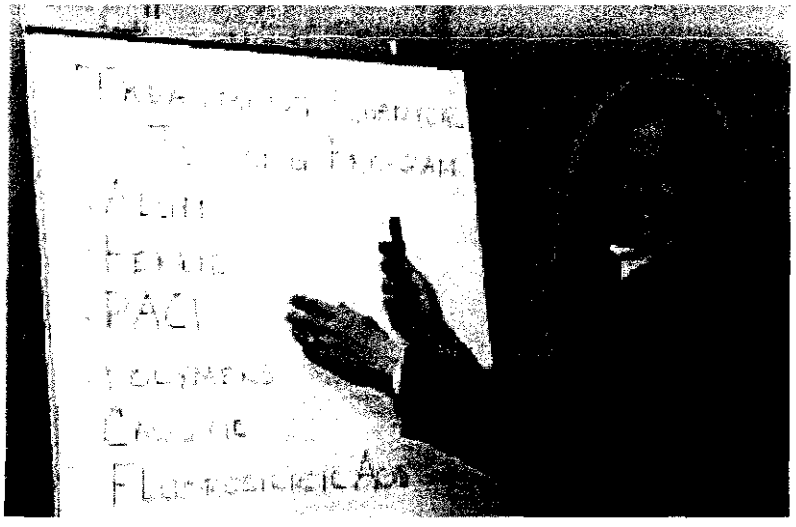
November 4 Served on a panel discussion at the International Riverbank Filtration Conference, Louisville, KY; entitled "Operation Issues of Riverbank Filtration"

December 14 Presentation at the Technologies and Strategies for Energy Efficient Utility Pumping Systems Conference of Indiana – AWWA, Terre Haute, IN; Energy Management Opportunities"

Kwok-Keung Au

August 18 Presentation at the American Water Works System, Quality Control and Research Laboratory, Belleville, IL, entitled "Particle/Particle Interactions in Aquatic Environments: Applications in Water Treatment Processes".

August 25 Presentation at the American Water Works System, Quality Control and Research Laboratory, Belleville, IL, entitled "Effects of Oxidation on Filtration Performance: The Role of Adsorbed Natural Organic Matter".



Robin J. Casale

March 28 Presentation at the Particle Measurement and Characterization in Drinking Water Treatment Symposium, AWWA, Nashville, TN, entitled "On-Line Particle Counter Selection and Use for Treatment Optimization."

December 2 Presentation at Advance Drinking Water Operators Training Class, Shrewsbury, NJ, entitled "Disinfection and CT."

Mark Denhart

June 1 Poster presentation at the 99th General Meeting of the American Society of Microbiology in Chicago, IL entitled "Development of a quantitative sequence detection (QSD) assay for Enteroviruses using TaqMan 7700 technology."

George Di Giovanni

April 29 Presentation at US Environmental Protection Agency Consultation on the Significance of *Cryptosporidium parvum* Strain Differences on Human and Animal Infection, Washington, DC entitled "Detection and hsp70 sequence analysis of infectious waterborne *Cryptosporidium parvum*."

May 31 Poster presentation at the 99th General Meeting of the American Society of Microbiology in Chicago, IL entitled "Quantitative sequence detection (QSD) of intact and infectious *Cryptosporidium parvum* oocysts."

August 30 Presentation at the AWWA International Symposium on Waterborne Pathogens, Milwaukee, WI entitled "Molecular characterization of naturally occurring infectious waterborne *Cryptosporidium parvum*".

October 6 Presentation at the 14th Annual Meeting of the Association of State Drinking Water Administrators, Orlando, Florida entitled "Use of Cell Culture-Polymerase Chain Reaction (CC-PCR) to Detect Infectious *Cryptosporidium parvum* in Drinking Water."

October 7 Presentation at the 13th Annual Meeting of the Association of State Drinking Water Administrators, Keystone, Colorado entitled "Detection of live, infectious *Cryptosporidium parvum* oocysts in water".

Richard Gullick

May 17 Presented a paper entitled "Early Warning Monitoring and Source Water Protection Survey of Surface Water Treatment Plants in the American Water System" at a workshop on Early Warning Monitoring to Detect Hazardous Events in Drinking Water Supplies sponsored by the Risk Science Institute of the International Life Sciences Institute at the U.S. Geological Survey headquarters in Reston, VA.

October 15 Presentation on "The Use of Sorbents to Retard Organic Contaminant Transport Through Soil-Bentonite Cutoff Wall Containment Barriers" at the School of Environmental Science, Engineering, and Policy at Drexel University in Philadelphia, PA.

Helen Hashemi

May 31 Poster presentation at the 99th General Meeting of the American Society of Microbiology in Chicago, IL entitled "Sequence analysis of PCR amplified hsp70 genes from infectious waterborne *Cryptosporidium parvum*."

Mohammad Karim

October 4 Presentation at the Project Team Meeting in Seattle, WA entitled "Occurrence of Indicator and Pathogenic Microorganisms External to the Distribution System."

Mark LeChevallier

February 11 Presentation entitled "Update: What is our Understanding of Pathogen Occurrence in Drinking Water" at the EPA Health Effects workshop in Washington, D.C.

February 24 Presentation to the New Jersey AWWA Operators course entitled "Controlling Biofilms." The program was sponsored by the Rutgers University Office for Continuing Professional Education. New Brunswick, NJ.

March 1 Presentation to the NJ-AWWA student chapter at the New Jersey Institute of Technology; Newark, NJ entitled "Detection and Control of *Cryptosporidium* in Water."

March 10 Presentation at the ICR Treatment, and Methods Research Stakeholders Meeting for the Stage 2 DBPT and LT2ESWTR, in Arlington, VA entitled "Characterization of the Occurrence of Pathogens and Indicators in Source Water"

March 12 Presentation at the ICR Treatment, and Methods Research Stakeholders Meeting for the Stage 2 DBPT and LT2ESWTR, in Arlington, VA entitled "Control of Microbial Contamination in Drinking Water Distribution Systems."

March 16 Presentation entitled "Biological filtration and Biofilm Control" at the Pennsylvania-American water quality functional meeting in Hershey, PA.

March 26 Presentation entitled "Advancements in Cryptosporidium Detection in Drinking Water," given at a meeting of Pfizer Pharmaceutical in Sandwich, UK.

March 19 Presentation entitled "Overview of *Cryptosporidium* - Progress Made in *Cryptosporidium* Identification – New Testing Techniques for Faster and More Reliable Results" at the Delaware River Basin Water Resources Association *Cryptosporidium* II Seminar at the Penn State Great Valley Campus in Malvern, PA.

March 29 Presentation at the Particle Measurement and Characterization in Drinking Water Treatment Symposium, Nashville, TN; "Particle Counting Experiences from Multiple Full-Scale Plants."

April 21 Presentation entitled "Detection of Infectious *Cryptosporidium parvum* Oocysts in Environmental Water Samples Using an Integrated Cell Culture-PCR (CC-PCR) System" at the International Conference on Minimizing the Risk from Cryptosporidium and Other Waterborne Particles in Paris, France.

June 2 Poster presentation at the 99th General Meeting of the American Society of Microbiology in Chicago, IL entitled "Pathogen Intrusion into Drinking Water Pipelines."

June 8 A presentation on "Variations of *Giardia* and *Cryptosporidium* in the Delaware River" at an AWWARF Workshop on Using Stakeholder Alliances in the Context of *Cryptosporidium* Control, in Philadelphia, PA.

June 15 An invited keynote speaker in the session on Novel Methodologies for Water Quality Monitoring at the 7th International Conference of the Israel Society for Ecology and Environmental Quality Sciences, held in Jerusalem, June 13 –18, 1999. The talk was sponsored by the Israel Academy of Sciences and Humanities.

July 8 Seminar entitled "Microbiological Aspects of Drinking Water Systems & Interrelationships Between Corrosion & Biofilms" at the Urban Watershed Management Branch, Water Supply and Water Resources Division, National Risk Management Research Laboratory in Edison, New Jersey.

July 21 A presentation on the Delaware River study and CC-PCR research was given at an EPA workshop to evaluate microbial risk analysis in Cincinnati, Ohio

August 2 Presentation entitled "Development of a 5-Year Research Agenda: A Utility Perspective on Drinking Water Research Needs" was given at the Association of Environmental Engineering and Science Professors at Penn State University, State College, PA.

September 8 Presentation entitled "Status of Additional Research on *Cryptosporidium* Occurrence" was given at a meeting of the Federal Advisory Committee Act (FACA) panel in Washington, D.C.

November 3 Presentation at the Water Quality Technology Conference 1999 in Tampa, FL entitled "Pathogen Intrusion into Potable Water."

November 3 Presentation at the Water Quality Technology Conference 1999 in Tampa, FL entitled "Treatment Strategies for Removal of Microbial and Other Contaminants from Spent Filter Backwash Water."

November 15 Presentation entitled "Exposure Assessment: Sources and Occurrence of Pathogens in Water" at the Second International Conference on the Safety of Water Disinfection: Balancing Chemical and Microbial Risk, in Miami Beach, FL.

December 10 Seminar presentation to the School of Environmental Science, Engineering, and Policy at Drexel University in Philadelphia entitled "Growth of Biofilm Bacteria in Drinking Water Distribution Systems."

Cheryl Norton

February 18 Presentation at AWWARF Technology Transfer Conference, Ft. Lauderdale, FL, entitled "Impact of Treatment Changes on Distribution System Biostability".

February 23 Presentation at Borchardt Conference, Ann Arbor, Michigan entitled "Biofilms – Impacts on Corrosion Control & on Finished Water Quality Changes".

March 10 Presentation at Southern Illinois Rural Water Association Meeting entitled "Biofilms in Distribution Pipes: Why are They Important and What Can We Do About Them?"

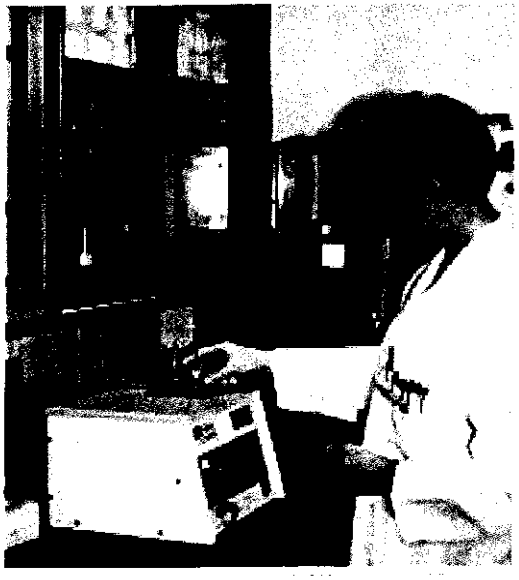
May 4 Presentation at Pennsylvania Section AWWA, Split Rock, PA entitled "Chloramination: Its Effect on Distribution System Water Quality".

June 20 Presentation at AWWA Workshop at the Annual Conference, Chicago, IL entitled "Assessing and Controlling Regrowth in Distribution Systems".

August 30 Presentation at International Symposium on Waterborne Pathogens, Milwaukee WI entitled "*Mycobacterium avium* in Drinking Water".

October 7 Presentation at Iowa Section AWWA, Council Bluffs, IA entitled "Maintaining Distribution System Water Quality".

October 21 Presentation at New York Section AWWA, Syracuse, NY, entitled "Evaluation and Control of Biological Regrowth".



Nancy Shaw

June 1 Poster presentation at the 99th General Meeting of the American Society of Microbiology in Chicago, IL entitled "An Improvement of the Assimilable Organic Carbon Assay".

Michael Spinner

June 1 Presentation at the 99th General Meeting of the American Society of Microbiology in Chicago, IL entitled "Viral Occurrence, Infectivity, and Identification in Groundwater Sites".

Dale Young

March 22 Presented a display on Microbial Analysis of Drinking Water at the Clean Water Celebration 99, in Peoria, IL.

Publications

Publication of research findings, especially in peer-reviewed journals and books, ensures that the American System Research meets the highest technical and professional standards. Inclusion of papers in conference proceedings and technical transfer seminars helps to quickly disseminate the research to users within the water industry.

Journals

Abbaszadegan, M., P. Stewart, and M. LeChevallier
A Strategy for Detection of Viruses in Groundwater by PCR. *Applied and Environmental Microbiology,* 65(2): 444-449.

AWWA Research Division Microbial Contaminant Research Committee
(M. LeChevallier chair). Committee Report: Emerging Pathogens – Bacteria. *Journal of the American Water Works*, 91(9): 101–109.

AWWA Research Division Microbial Contaminant Research Committee
(M. LeChevallier chair). Committee Report: Emerging Pathogens – Viruses, Protozoa, and Algal Toxins. *Journal of the American Water Works Association,* 91(9): 110–121.

AWWA Roundtable Discussion
The Disinfectant Residual Dilemma. *Journal of the American Water Works Association,*
91(1): 24-30.

Au, K.-K., A.C. Penisson, S. Yang, and C.R. O'Melia
Natural organic matter at oxide/water interfaces: Complexation and conformation, *Geochimica et Cosmochimica Acta*, 63: 2903-2917.

Di Giovanni, G. D., F. H. Hashemi, N. Shaw, M. LeChevallier, and M. Abbaszadegan
Detection of infectious *Cryptosporidium parvum* oocysts in surface and filter backwash water samples using immunomagnetic separation (IMS) and integrated cell culture-PCR (CC_PCR). *Applied and Environmental Microbiology,* 65:3427-3432.

Di Giovanni, G. D., L. S. Watrud, R. J. Seidler and F. Widmer
Comparison of parental and transgenic alfalfa rhizosphere bacterial communities using Biolog GN metabolic fingerprinting and enterobacterial repetitive intergenic consensus sequence-PCR (ERIC-PCR). *Microbial Ecology*, 37:129-139.

Di Giovanni, G. D., L. S. Watrud, R. J. Seidler and F. Widmer
Fingerprinting of mixed bacterial strains and Biolog Gram negative (GN) substrate communities by enterobacterial repetitive intergenic consensus sequence-PCR (ERIC-PCR). *Current Microbiology,* 38:217-223.

Donegan, K. K., R. J. Seidler, J. D. Doyle, L. A. Porteous, G. Di Giovanni, F. Widmer, and L. S. Watrud
A field study with genetically engineered alfalfa inoculated with recombinant Sinorhizobium meliloti: effects on the soil ecosystem. *Journal of Applied Ecology*. 36:920-936.

LeChevallier, M.W
1999. The Case for Maintaining a Disinfectant Residual. *Journal of the American Water Works Association*, 91(1): 86-94.

Nowack, K.O., F.S. Cannon, and H. Arora
Ferric Chloride plus GAC for removing NOM. *Journal of the American Water Works Association*, 91(2): 65-78.

Volk, C. J., and M. W. LeChevallier
Impacts of the reduction of nutrient levels on bacterial water quality in distribution systems. *Applied and Environmental Microbiology*, 65(11): 4957-4966.

Book Chapters

Geldreich, E.E. and M. W. LeChevallier.
Microbial Water Quality in Distribution Systems. pp. 18.1-18.49, In: R. D. Letterman (ed), *Water Quality and Treatment, 5th edition*, McGraw-Hill, NY.

LeChevallier, M.W., M. Abbaszadegan, A.K. Camper, G. Izaguirre, M. Stewart, D. Naumovitz, M. Marshall, C.R. Sterling, P. Payment, E.W. Rice, C.J. Hurst, S. Schaub, T.R. Slifko, J.B. Rose, H.V. Smith, and D.B. Smith
Emerging Pathogens: Names to Know and Bugs to Watch Out For. pp. 136-172. *Identifying Future Drinking Water Contaminants*. National Academy Press, Washington, DC.

LeChevallier, M.W.
Biofilms in Drinking Water Distribution Systems: Significance and Control. pp. 206-219. *Identifying Future Drinking Water Contaminants*. National Academy Press, Washington, DC.

LeChevallier, M.W.
Biofilms in Water Distribution Systems: Control and Remediation. pp. 220-230. In: C. W. Keevil, A. Godfree, D. Holt, and C. Dow (eds.), *Biofilms in Aquatic Systems*, Royal Society of Chemistry, Cambridge, UK.

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Giardia *Cysts and* Cryptosporidium *Oocyst Survival in Watersheds and Factors Affecting Inactivation*. AWWA Research Foundation and American Water Works Association. Denver, CO.

Conference Proceedings

Abbaszadegan, M., M. Denhart, M. Spinner, G. Di Giovanni, M. LeChevallier.
Identification of viruses present in ground water cell culture harvest by PCR. Proceedings of the Water Quality Technology Conference, Tampa, FL, October 31-November 3. American Water Works Association, Denver, CO.

Abbaszadegan M., and G. D. Di Giovanni.
Development of a quantitative sequence detection (QSD) assay for enteroviruses using TaqMan 7700 technology. Proceedings of the Water Quality Technology Conference, Tampa, FL, October 31-November 3. American Water Works Association, Denver, CO.

Aboytes, R.; Di Giovanni, G.; Abbaszadegan, M.; Abrams, F.A.; Rapoff, C.A. and LeChevallier, M. W.
Finished Water Monitoring for Infectious *Cryptosporidium* Oocysts using Immunomagnetic Separation (IMS) and Cell Culture-Polymerase Chain Reaction Method (CC-PCR). Proceedings of the Water Quality Technology Conference, Tampa, FL, October 31-November 3. American Water Works Association, Denver, CO.

Arora, H., M. LeChevallier, and G. DiGiovanni
Treatment Strategies for Removal of Microbial and Other Contaminants from Spent Filter Backwash Water. Proceedings of the Water Quality Technology Conference, Tampa, FL, October 31-November 3. American Water Works Association, Denver, CO.

Arora, H., M.W. LeChevallier, and J. Routt
Application of Particle Counting to Enhance Water Treatment Operations. Particle Measurement and Characterization in Drinking Water Treatment Symposium, Nashville, TN.

Arora, H., M.W. LeChevallier, J. Hanchak, and M. Burns
Particle Counting Experiences with Multiple Full-Scale Plants. Particle Measurement and Characterization in Drinking Water Treatment Symposium, Nashville, TN.

Bouwer, E., J. Weiss, W. Ball, C. O'Melia, and H. Arora
Water Quality Improvements During Riverbank Filtration at Three Midwest Utilities. International Riverbank Filtration Conference, Louisville, KY

Casale, R.J., E. Ibrahim and K. Dixon.
On-Line Particle Counter Selection and Use for Treatment Optimization. Particle Measurement and Characterization in Drinking Water Treatment Symposium, Nashville, TN.

Di Giovanni, G.D., J.W. Czajka, M.E. Schaffer, G. Tice, M.W. LeChevallier, and M. Abbaszadegan.
A fluorescent homogeneous format PCR kit for the detection of *Cryptosporidium parvum*. Proceedings of the Water Quality Technology Conference, Tampa, FL, October 31-November 3. American Water Works Association, Denver, CO.

Di Giovanni, G.D., M. Denhart, M.W. LeChevallier, M. Abbaszadegan.
Quantitation of intact and infectious *Cryptosporidium parvum* oocysts using quantitative sequence detection (QSD). Proceedings of the Water Quality Technology Conference, Tampa, FL, October 31-November 3. American Water Works Association, Denver, CO.

Frey, M.M., J.S. Rosen, L.P. Sullivan, J. Sobrinho, and M. LeChevallier
Monitoring US Source Waters for *Cryptosporidium*. Proceedings of the Water Quality Technology Conference, Tampa, FL, October 31-November 3. American Water Works Association, Denver, CO.

Friedman, M., G. Kirmeyer, K. Martel, J. Funk, M. LeChevallier, and M. Jackman
Pathogen Intrusion into the Distribution System: Is Your System at Risk? Proceedings of the Water Quality Technology Conference, Tampa, FL, October 31-November 3. American Water Works Association, Denver, CO.

Funk, J.E., D.J. Wood, S.J. Vuuren, M.W. LeChevallier, M. Friedman
Pathogen Intrusion into Distribution Systems Due to Transients. 3rd ASME/JSME Joint Fluids Engin. Conf., San Francisco, CA.

Lovins, W.J. Taylor, R. Kozik, M. Abbaszadegan, M. LeChevallier, and K. Ajy
Multi-Contaminant Removal by Integrated Membrane Systems. Proceedings of the Water Quality Technology Conference, Tampa, FL, October 31-November 3. American Water Works Association, Denver, CO.

LeChevallier, M.W., M.R. Karim, M. Abbaszadegan, J.E. Funk, and M. Friedman.
Pathogen Intrusion into Potable Water. Proceedings of the Water Quality Technology Conference, Tampa, FL, October 31-November 3. American Water Works Association, Denver, CO.

Singer, P.C., H. Arora, E. Dundore, H. Brophy, and H.S. Weinberg
Control of Haloacetic Acid Concentrations by Biofiltration – A Case Study. Proceedings of the Water Quality Technology Conference, Tampa, FL, October 31-November 3. American Water Works Association, Denver, CO.

Visits to the Research Department

The importance of visits from colleagues can be summarized in sharing information, research planning, and face-to-face discussion of results. These visits are mutually advantageous to avoid costly duplication of research effort. Visitors during 1999 included:

Dr. Susan Boutros
President of Environmental Associates to learn about the CC-PCR method for *Cryptosporidium*.

Dr. Jose J. Hernandez
A board certified pathologist from the Missouri Baptist Hospital, to discuss applications of the micromanipulation technique for the separation of single *Cryptosporidium* oocysts.

Keith Cadee and Gary Watson
Water Corporation, Western Australia ; to discuss the use of MIEX, a powdered polymeric resin, for control of natural organic matter in source water.

Dr. Benito Marinas and Nathan Dunahee
From University of Illinois at Urbana-Champaign, to discuss techniques for enumerating and identifying *M. avium*. They are currently working on a project to evaluate disinfection kinetics of *E. coli* and *M. avium*.

Mark Ford and Stewart Sanders
Chief executive and project manger of WaterCare, a New Zealand water utility, to discuss American's research program.

John O'Brien
From the University of Illinois Dept. of Civil and Environmental Engineering

Health Advisory Committee
An advisory committee of experts addressed the issue of detecting infectious *Cryptosporidium* oocysts in drinking water and developed various action plans:

Person	Agency	Function
Dennis Juranek	CDC	Director, Parasitology
Stig Regli	EPA	Rule manager
Jeff Rosen	TPMC	Statistician
Jim Miller	NYC Health Dept.	CSTE representative*
Rebecca Calderon	EPA	Epidemiologist

** CSTE – Council of State and Territorial Epidemiologists*

Fred Cannon, Pat Hatcher, and Graduate Students
Fred Cannon of Penn State University, Pat Hatcher of Ohio State University and several graduate students gave a series of lectures on a new project to characterize natural organic matter in drinking water. Presentations were also given on GAC reactivation, the role of calcium adsorption, and minimizing the pH effect following regeneration.

Scott Fritschel, Peter Mrozinski, and John Czajka
Qualicon, visited to discuss plans for *Cryptosporidium* testing.

Committee Activities

Morteza Abbaszadegan

- AWWARF Project Advisory Committee (PAC) member for the AWWARF project entitled Effect of Various Disinfection Methods on the Inactivation of *Cryptosporidium*.
- Member — Groundwater Rule sponsored by AWWA and EPA.
- Member of AWWA Organisms in Water Committee, subcommittee to develop the new Waterborne Pathogens Manual.

Ramon Aboytes

- Member of the AWWARF Project Advisory Committee for the project entitled "Structural Physiology of the *Cryptosporidium Oocyst* Wall as it Relates to Drinking Water Treatment."

Harish Arora

- Member – AWWA Research Division committee on Organic Contaminants. Developed and reviewed research projects for AWWARF funding and developed a Sunday seminar on Endocrine Disruptors for the 2000 Annual AWWA Conference.
- Member – AWWA Disinfection By-Products TAW. Prepared AWWA's positions for Stage 2 rules through analysis of ICR and other survey data.
- AWWARF Project Advisory Committee member for a project on Removal of MTBE by Advanced Oxidation Processes.

Kwok-Keung Au

- Member of the AWWA Standards Committee on Iron Salts, Aluminum Salts, and Related Coagulant Aids.

Robin J. Casale

- Chair — NJ AWWA Student Affairs Committee. Developed a website related to drinking water issues for children grades K-6 (www.njawwa.org/kidsweb).
- Representative — NJ AWWA Strategic Planning Committee.
- Member — NJ AWWA Scholarship Ad Hoc Committee.

George Di Giovanni

- Member of the AWWARF Project Advisory Committee for the project entitled "Novel Methods to Determine *Cryptosporidium* and *Giardia* Viability."
- Member of the AWWARF Project Advisory Committee for the project entitled "Integral Optimization of Ozone Disinfection Systems With Fluorescent-Dyed Polystyrene Microspheres."
- Member of the AWWA Microbial Contaminants Committee.

Richard Gullick

- Vice-Chair of the AWWA Organic Contaminants Control Committee. Assisted in development of a plan for Committee projects.
- Member - AWWA Source Water Protection Committee. Participated in development of a survey of state plans for source water assessment and protection programs. Co-authored an article for the committee newsletter titled "AWWARF Research Project Investigates Early Warning and Source Water Monitoring Systems."
- Member – New Jersey Water Environment Association Hazardous Waste Committee. The committee investigates problems related to hazardous wastes and groundwater contamination.

Mohammad Karim

- Member of the AWWA Microbial Contaminants Committee.

Mark LeChevallier

- Chairman of the AWWA Microbial Research committee. The committee collaborated in organizing a specialty conference on particle counting and characterization, and published manuscripts on emerging pathogens in *JAWWA*.
- Member — Standard Methods committee for Stressed Organisms, 9212; Heterotrophic Bacteria, 9215; Assimilable Organic Carbon. Section 9217; Coliforms, 9222; Pathogenic Protozoa; 9711.
- Member — AWWA Microbial and Disinfection TAW. Major projects included review of Stage 1 Disinfectant/Disinfection By-Product Rule and Interim Enhanced Surface Water Treatment Rule guidance manuals, ICR data analysis, and development of positions for Stage 2 rules.

- Member of the ICR Technical Workgroup. The workgroup met several times to formulate specific data analyses to answer pending regulatory questions.
- Member of the Environmental Microbiology subcommittee for the Public Science Advisory Board of the American Society for Microbiology. The committee developed a report detailing the need for an integrated approach in federal regulation of microbes water (drinking, waste, bathing, agricultural, shellfish).
- Chair of Division Q (Applied and Environmental Microbiology). Elected by division members to serve a 2-year term. Organized abstracts and program for the annual conference.
- Editorial Board for the Journal of *Applied and Environmental Microbiology*.
- Disinfection By-Product Council, Technical Advisory Group member. Review and recommend research projects for funding.
- EPA Peer Reviewer. Participated in a peer-review group to select research projects for EPA funding.
- Member, Microbiology Review Committee for *Cryptosporidium*, *Giardia* and *Cyclospora*. World Health Organization. Developed a white paper on microbial treatment.
- External Reviewer, for the University of Central Florida for the Ph.D. thesis committee of Isabel Escobar.

Cheryl Norton

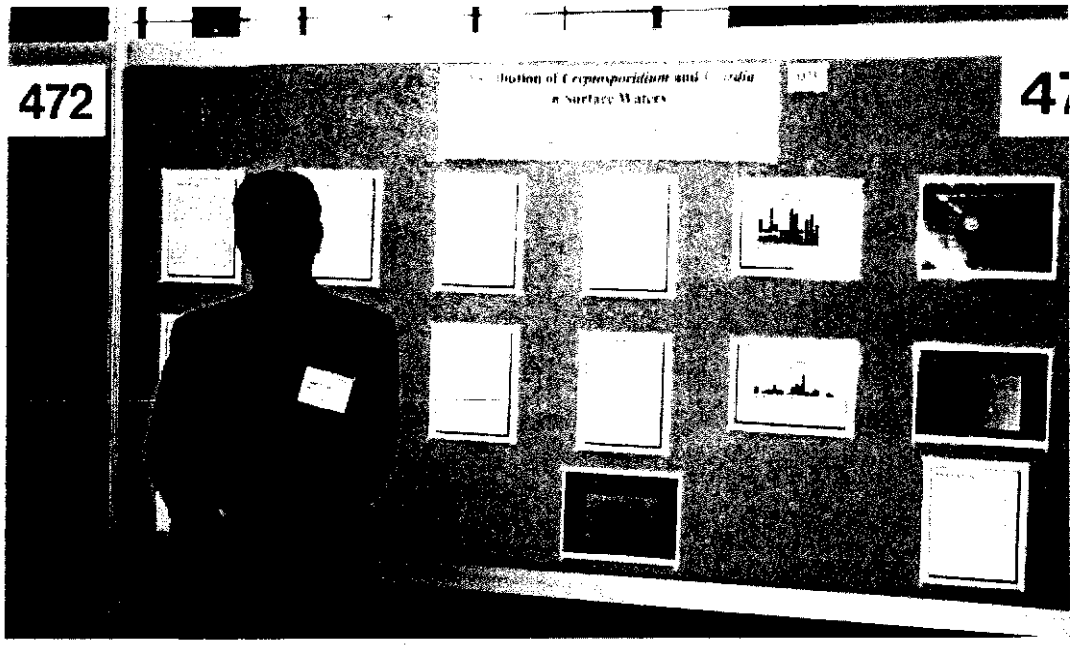
- Member of the AWWARF Project Advisory Committee for the project entitled "Rapid Screening of Pathogens in Water."
- Member of the AWWARF Project Advisory Committee for the project entitled "Innovative Biofilm Prevention Strategies."

Other Activities

Support of American operations is an important service of the Research Program. Besides being a technical resource for company operations, the Research Department can provide analytical support not found in water company laboratories. During 1999, the Research Program provided analytical or technical services to AWS and other water companies.

Morteza Abbaszadegan

- Moderated an EPA session "Cryptosporidium Species Systematics and Waterborne Challenges in Public Health" in Washington, D.C., April 29 and 30.
- Appointed chair of the AWWA Microbiological Contaminants Research Committee for a three-year term.



Ramon Aboytes

- Prepared a display on Microbial Analysis of Drinking Water presented at the Clean Water Celebration 99, Peoria, IL., March 22.
- Attended a Conference for Managers and Supervisors, April 22 in St. Louis, MO.
- Visited with researchers on November 16 at the Advanced Reproductive Technologies Center, Missouri Baptist Hospital, in St. Louis, MO to discuss the use of Pico-injectors.

Kimberly Ajy

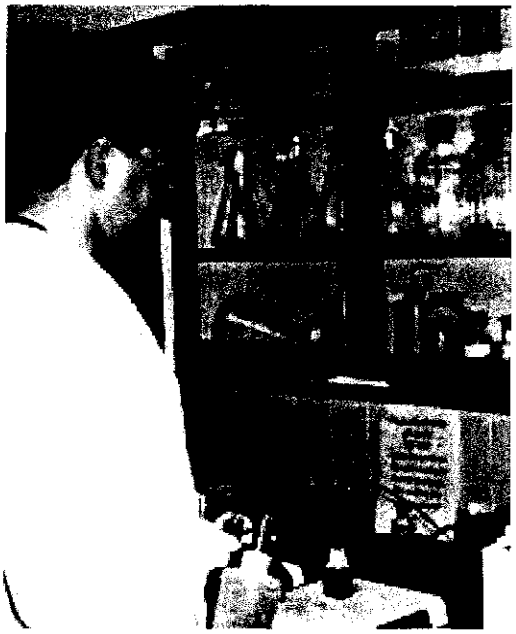
- Judged poster and speaker sessions for undergraduate and graduate students for the Students Affairs Committee of the NJAWWA at the annual conference in Atlantic City.

Kwok-Keung Au

- Collaborated with St. Louis Section, American Chemical Society (ACS) to launch a new discussion group in Environmental Science.

Harish Arora

- Recipient of the AWWA Distribution and Plant Operations Division Best Paper Award for the manuscript "Energy Management Opportunities."
- Reviewer for the *Journal of the American Water Works Association.*
- Attended the American Society of Civil Engineers' 1999 Environmental Engineering Conference, July 25-28, Norfolk, VA.
- Attended the USEPA's Data Reliability Stakeholder Workgroup meeting as part of the Federal Safe Drinking Water Information System (SDWIS/FED) program, September 8 –9, Washington DC.



Robin J. Casale

- Attended the New Jersey Section AWWA annual meeting, March 23-25, Atlantic City, NJ. Coordinated and judged poster and speaker presentations for undergraduate and graduate student awards.
- Attended AWWA Northeast Regional Meeting of Section Officers, October 15-16, Westbrook, CT.
- Attended Second Annual Women in Science Symposium, Rutgers University / UMDNJ-Robert Wood Johnson Medical School, October 13, Piscataway, NJ.
- Attended the AWWA Water quality Technology Conference, October 31-November 3, Tampa, FL.
- Attended AWWA Teleconference entitled, "The Disinfection By-Product and Surface Water Treatment Rules: Operational Issues and Treatment Strategies," November 9.
- Coordinated and attended NJAWWA Student Affairs Committee presentations.

George Di Giovanni

- AWWA Workshop Moderator, "Detection and Quantitation of Infectious *Cryptosporidium*." Microbial Contaminants Committee, Water Quality Technology Conference, October 31, 1999, Tampa, Florida.
- Administered a week long training workshop February 8-12, on the *Cryptosporidium* CC-PCR infectivity assay. The workshop was for two guests from the Netherlands, Bart Wulllings (KIWA) and Ciska Schets (RIVM); Simin Abrishami from NSF International.
- Attended the National Symposium on Medical and Public Health Response to Bioterrorism, held in Washington, D.C., February 16 and 17.
- Attended the Midwestern Molecular Microbial Ecology meeting at the University of Illinois August 1-3.
- Prepared a summary of the CC-PCR and QSD methods entitled Detection and Quantitation of Intact and Infectious *Cryptosporidium parvum* in Water for a patent application.
- Participated in meetings with Qualicon representatives to discuss the future development and commercialization of a *C. parvum* PCR detection kit.

Richard Gullick

- Attended the 1999 Water Quality Association Convention and Exhibition in Ft. Worth, TX from March 18 - 20, 1999.
- Attended the New Jersey Water Environment Association Annual Conference in Atlantic City, NJ on May 6, 1999.
- Attended the AWWA Water Resources Conference in Norfolk, VA on September 28, 1999.
- Attended the AWWA Water Quality Technology Conference and a preconference workshop on "The Fundamentals of Water Quality and Treatment Chemistry." in Tampa, FL October 31 – November 3, 1999.
- Attended the Delaware River Watershed-Wide Conference "Flowing Toward the Future: 21st Century Directions for the Delaware River and its Watersheds" on November 16, 1999 in Philadelphia, PA.
- Attended the AWWA Satellite Teleconference on "Operations & Maintenance: Tools & Techniques to Protect Water Quality in the Distribution System" on March 11, 1999 in Voorhees, NJ.
- Attended the AWWA Source Water Protection Professional Development Seminar from April 8-9, 1999 in Milwaukee, WI.
- Participated in a Project Advisory Committee meeting for AWWARF Project 2527 (Design of Early Warning and Predictive Source Water Monitoring Systems) in Cincinnati, OH on October 13, 1999.
- Participated in a workshop on "Early Warning Monitoring to Detect Hazardous Events in Drinking Water Supplies" sponsored by the Risk Science Institute of the International Life Sciences Institute (ILSI) at the U.S. Geological Survey headquarters in Reston, VA on May 17-18, 1999.
- Met with representatives of the Ohio River Valley Water Sanitation Commission in Cincinnati, OH on October 12, 1999 to discuss their operation.
- Organized and attended a meeting with representatives of Yellow Springs, Inc. (a monitoring equipment manufacturer located near Dayton, OH) and representatives of academia, consulting, water utilities, and the USEPA on October 14, 1999 to discuss the needs of the water industry for monitoring equipment and potential research projects to meet these needs.
- Co-authored an article submitted for publication in the AWWA Source Water Protection committee's newsletter The Source titled "AWWARF Research Project Investigates Early Warning and Source Water Monitoring Systems."
- Reviewer — of a chapter in a book titled "Physicochemical Remediation of Contaminated Ground Water."

Mohammad Karim

- Participated in the round robin method validation test of EPA method 1601 entitled " Coliphage in Water by Two-Step Enrichment Presence-Absence, Colorimetric Presence-Absence, and Single Agar Layer Procedures".
- Reviewer – *Journal of the American Water Works Association.*
- Reviewer – Standard Method for the Detection of Coliphage, Section 9224.

Mark LeChevallier

- Recipient of the AWWA Distribution and Plant Operations Division Best Paper Award for the manuscript "Energy Management Opportunities."
- Foundation for Microbiology Lecturer. A two-year appointment by the American Society for Microbiology to provide travel funds for distinguished lecturer to present at regional section meetings.
- Judge at the Coriell Institute Science Fair. March 6.
- Attended the EPA workshop on UV disinfection in Arlington, VA on April 28-29.
- Participated in a workshop on "Early Warning Monitoring to Detect Hazardous Events in Drinking Water Supplies" sponsored by the Risk Science Institute of the International Life Sciences Institute (ILSI) at the U.S. Geological Survey headquarters in Reston, VA on May 17-18, 1999.
- Participated in a meeting with the faculty of the Environmental Engineering Department at Drexel University to discuss research needs for the water industry on June 30.
- Attended a workshop on September 1-2 entitled "Clearinghouse Priorities for Microbial Risk Assessment." organized by the Joint Institute for Food Safety and Applied Nutrition (JIFSAN), to review and recommend the content of a web-based information center on microbial risk assessment.
- Participant in a USEPA and AWWARF Drinking Water Research Needs Expert Panel on September 27-29 in Leesburg, VA. The workshop categorized, prioritized, and developed a research plan for the 50 chemical and 10 microbial contaminants on EPA's Candidate Contaminant List.
- Attended the EPA/CDC workshop on Waterborne Disease Occurrence in Washington, DC on November 18.

- Participated in the NJ-AWWA Fuller Award luncheon.
- Consultant. Collaborated with Killam Associates on a project for Passaic Valley Water Commission to study chloramination and biofilm control in their distribution system.
- Reviewer. Reviewed technical papers for *Journal of the American Water Works Association, Applied and Environmental Microbiology, Water Research, Journal of Emerging Infectious Disease*, various EPA stage 1 DBP/ESWTR guidance manuals, and a proposal from the CRC for Water Quality and Treatment in Salisbury, Australia.

Cheryl Norton

- Processed *Mycobacterium* samples for the Spooner, WI water utility. The utility requested assistance in dealing with a *Mycobacterium* problem.

Chris Rapoff

- Attended the ATCC sponsored "Recombinant DNA: Techniques and Applications Workshop" in Manassas, VA, October 4-8.

Michael Spinner

- Attended the Midwestern Molecular Microbial Ecology meeting at the University of Illinois August 1-3.

Dale Young

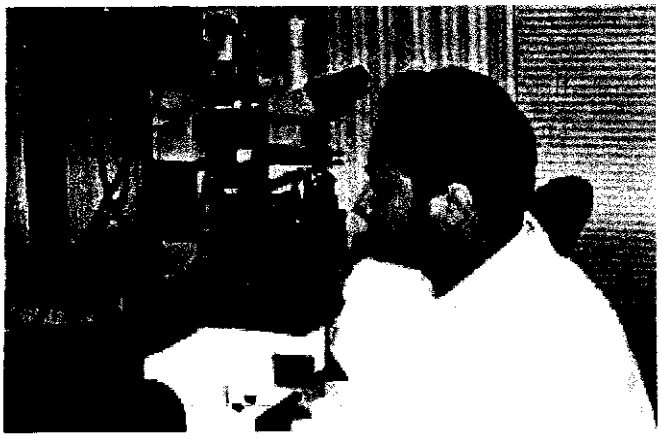
- Prepared a display on Microbial Analysis of Drinking Water presented at the Clean Water Celebration 99, Peoria, IL, March 22.

THE AMERICAN WATER SYSTEM

Research Reports

Source Water

- Radon in Well Supplies – Occurrence and Removal Data and Recommendations for the American Water Works System. May 1987.
- Effect of Tri-County Project Water Quality on Contiguous Supplies. June 1992.
- Source Water Characterization. December 1993.
- Application of PCR Technologies for Virus Detection. February 1997.
- Survey of Open Finished Water Reservoirs for Giardia Cysts and Cryptosporidium Oocysts. February 1997.
- Radon Evaluation. December 1997.
- Variation of Giardia and Cryptosporidium Levels in the Delaware River. April 1998.
- Occurrence of Perchlorate and Methyl Tertiary Butyl Ether (MTBE) in Groundwater of the American Water System. September 1998.
- Occurrence of Viruses in Ground Water in the United States. October 1999.
- The Effect of Wastewater Discharge and Rainfall on Giardia and Cryptosporidium in East Central Illinois. October 1999.
- Radon Treatment Cost Evaluation. December 1999.
- Variability of Pathogens in Source Waters. *
- Continuous Monitoring of Source Waters and Spill Control Response. *
- Impacts of Major Point and Non-Point Sources on Raw Water Treatability. *
- Pharmaceutically Active Compounds. *



* *Denotes project in progress*

TREATMENT

Pretreatment

- Study of Water Quality Improvements During Bank Filtration of River Waters.*

Coagulation - Sedimentation

- Dissolved Air Flotation for Clarification of a Highly Colored Water. September 1984.
- Evaluation of the Roberts-Haber Adsorption Process. February 1987.
- Investigation of High Rate Solids Contact Clarification-Kentucky American Water Company. August 1987.
- Investigation of Rapid Mix Technology - Recommendations for the American Water System. December 1987
- Residual Aluminum in Finished Water. December 1988.
- Evaluation and Pilot-Scale Testing of the Adsorption Clarifier. August 1990.
- An Evaluation and Pilot-Scale Testing of the Adsorption-Clarifier at the Canoe Brook Station, New Jersey American. November 1990.
- Quality Impacts of Water Stream Recycling. June 1993.
- Enhanced and Optimized Coagulation for Particulate and Microbial Removal. July 1998.
- Enhanced Solids Contact Clarification for Removal of Natural Organic Matter. April 1999.

Filtration

- Performance of Full Scale GAC Treatment for Removal of Organic Compounds from Groundwater. June 1984.
- Pilot Scale Investigation of Direct Filtration - Keystone Water Company, Moshannon Valley District. August 1985.
- Investigation of Direct and Slow Sand Filtration - KWC - Bangor District. July 1986.
- Evaluation of the Substitution of GAC for Sand Filter Media, University of Illinois. 1986.
- Evaluation of Chemical Pretreatment and Filter Media to Optimize Filtration Effectiveness, Connecticut-American Water Company. January 1988.
- Reactivation and Reuse of Granular Activated Carbon – Recommendations for the American Water System. October 1988.
- Investigation of Ozone - Direct Filtration and High Rate Clarification Processes at Connecticut-American Water Company. July 1991.
- A Performance Evaluation of the Pacer II and Trident Systems. June 1992.
- Performance of Filter-Media Retaining Underdrains. March 1998.
- Application of Particle Counting to Enhance Water Treatment Operations. April 1998.
- Effects of Oxidation on Filtration Performance: The Role of Adsorbed Natural Organic Matter. *

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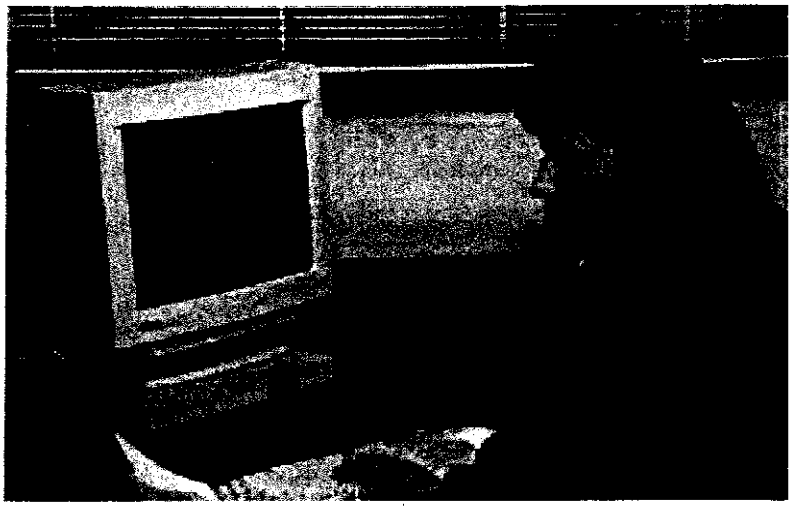

Disinfection - DBP Reduction

- THM Occurrence and Control in the American Water Works Systems. April 1983.
- Investigation of THM Precursor Reduction Using Chlorine Dioxide. March 1985.
- Evaluation of Ozone for Potential Use in the American System. June 1989.
- The Effect of Sulphur-Based Reducing Agents and GAC Filtration on Chlorine Dioxide By-Products. August 1990.
- An Evaluation of the Impact of Current and Future Disinfection/Disinfection By-Product Regulations on the Kentucky-American Water Company. June 1993.
- Disinfection By-Products – American System Survey of Occurrence, Control and Fate. November 1994.
- Evaluation of Chlorine Dioxide for Inactivation of Cryptosporidium and By-Product Control. February 1998.
- Characterizing NOM using TMAH Thermochemolysis. *
- Formation, Occurrence, Stability, and Dominance of HAAs and THMs in Treated Drinking Water. *

Other Treatment Technologies

- Evaluation of Water Treatment Techniques for Hingham Water Company. October 1983.
- Evaluation of Alternatives for Treatment of Organic Contamination at Highland Avenue Station. June 1984.
- Evaluation of an In-Ground Iron and Manganese Removal Process. June 1985.
- An Evaluation of Aeration Technology for Radon Removal. November 1989.
- Evaluation of Membrane Desalination - Cape May, New Jersey. December 1993.
- Evaluation of Dissolved Air Flotation for Water Clarification and Sludge Thickening. May 1994.
- Impact of Calcium Adsorption on Thermal Reactivation of Granular Activated Carbon. June 1998.

* *Denotes project in progress*

- Nanofiltration for Control of DBP Precursors and Pathogenic Microorganisms. *
- Occurrence and Problems Associated with Contaminants in Drinking Water Treatment Chemicals. *
- Manganese Control and Permanganate Residual Measurement. *

Waste Products

- Water Plant Waste Handling and Treatment. October 1983.
- An Evaluation of Alternatives for Treatment Residuals Management - Monmouth Consolidated Water Company. November 1985.
- An Evaluation of Alternatives for Treatment Residuals Management - Commonwealth Water Company. January 1986.
- An Evaluation and Comparative Analysis of Alternative Methods for Dewatering Water Treatment Residuals. December 1987.
- Mechanical Sludge Freezing - Pilot Plant Investigation. April 1988.
- An Evaluation of Alternatives for Treatment Residuals Management, Pennsylvania Region. June 1988.
- Evaluation of Residuals Management Alternatives for West Virginia-American Water Company. December 1992.
- Evaluation of Chemical and Physical Characteristics of Water Treatment Sludges Before and After a Freeze-Thaw Cycle - Penn State University. June 1993.
- Treatment Strategies for Spent Filter Backwash Water. October 1999.

Distribution

- Investigation of Plastic Pipe Permeation by Organic Chemicals. November 1984.
- Examination and Characterization of Distribution System Biofilm. March 1987.
- Disinfection of Bacterial Biofilms. August 1987.
- Lead at the Tap - Sources and Control: A Survey of the American Water System. August 1988.
- Disinfection of Biofilms in a Model Distribution System. October 1989.
- Implementation of Chloramination and Corrosion Control to Limit Microbial Activity in the Distribution System. March 1995.
- Factors Limiting Microbial Growth in Distribution Systems. January 1996.
- Impact of Nutrient and Corrosion Control on Bacterial Levels in a Model Distribution System. November 1998.
- Leaching of Metals from Water Meters. November 1998.
- Occurrence and Control of *Mycobacterium avium* Complex.*
- Pathogen Intrusion in the Distribution System.*
- Case Studies of the Impacts of Treatment Changes on Biostability in Full-Scale Distribution Systems: the Delaware River Regional Water Treatment Plant. *

* *Denotes project in progress*

Microbiology

- Bacterial Association with GAC particles, Montana State University. 1985.
- Bacterial Regrowth in Distribution System, Montana State University. 1986.
- Use of Monoclonal Antibodies for Parasite Detection. August 1988.
- Bacterial Nutrients in Drinking Water. June 1989.
- Modeling of Chlorine Inactivation of Pipe Biofilm. July 1989.
- Assessing and Controlling Bacterial Regrowth in Distribution Systems, University of California, Montana State University. December 1989.
- Evaluation of Current Treatment Practices for Removal of Waterborne Parasites. December 1990.
- Methodology for Rapid Coliform Detection, Yale University. March 1991.
- Application of Biological Water Treatment Processes. April 1991.
- Evaluation of AOC Measurement and Bacterial Regrowth Techniques. December 1991.
- Relationship between Corrosion and Disinfection of Biofilm Bacteria. July 1992.
- Monitoring of Giardia and Cryptosporidium Monitoring in the American Water System. December 1993.
- NJDEP Survey of Source Water for Giardia Cysts and Cryptosporidium Oocysts. June 1995.
- Survey of Assimilable Organic Carbon and Coliform Regrowth in the American Water System. December 1996.
- Microbial Impact of Biological Filtration. May 1997.
- Biodegradable Organic Matter: Significance and Changes During Conventional Water Treatment. December 1997.

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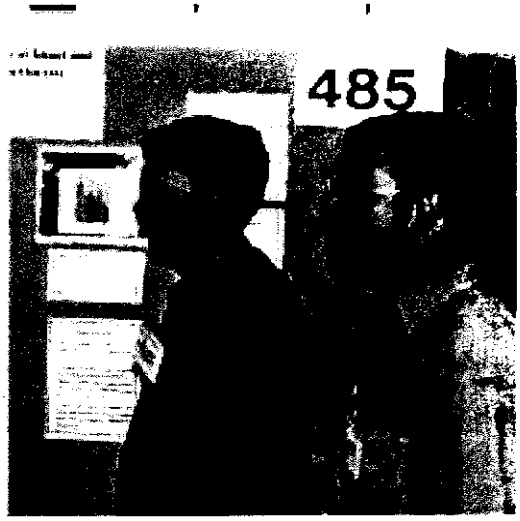

- Giardia Cyst and Cryptosporidium Oocyst Survival in Watersheds and Factors Affecting Inactivation. September 1998.
- Cryptosporidium parvum Viability Assay Using Integrated Cell Culture and PCR.*
- Finished Water Cryptosporidium Monitoring. *

TASTE & ODORS

- Evaluation of Ozone and GAC for Taste and Odor Control at Pennsylvania American-Norristown November 1989.
- Taste and Odors Associated with Chlorine Dioxide, Virginia Tech. 1991.
- Practical Taste-and-Odor Methods for Routine Operations: Decision Tree. *

MANAGEMENT ISSUES

- Capital Cost Impacts of the 1986 Safe Drinking Water Act Amendments to the American Water System. October 1991.
- Systemwide Water Quality Database – Feasibility and Implementation. January 1992
- Meter Reading Management – Phase I Report: An Assessment of Key Issues Associated with Current Meter Reading Practices. February 1994.
- Energy Management Opportunities in the American Water System. November 1995.
- Meter Reading Management Study: Advanced Metering Systems. April 1996.
- Production Facility Management Study: Automation Strategies for the American Water System. October 1996.
- Customer Service Perception. *
- Maintenance and Staffing . *

* *Denotes project in progress*

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